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Insect Distribution Studies II

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Behavior of any species of insect or other organism when introduced into a new territorial environment is often, but not always, inconsistent with its previous history. A careful study of distributional data along with behavioral phenomena of introduced insects is at the same time very interesting and frustrating. When conclusions are reached, although these can be only tentative, they may be helpful in learning to live with the introduced pest species.

An earlier study (Allen, 1963) analyzed the history of olive scale in the United States, and included essential background material applicable to this and future efforts. This paper will attempt to bring up to date the history and distributional patterns of several more introduced insects. Coverage will be limited to California. This will not be so lengthy as the work on olive scale; partly because the patterns seem less complicated, and partly in the interest of covering more species. Species to be considered here are unrelated but have the following in common: (1) They have all been introduced into California within the last 75 years. (2) They have attracted considerable attention as actual or potential plant pests. (3) They have been in California long enough that a pattern is discernible.

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Collection records of the California Department of Agriculture, and personal observations in the field, are the primary sources of this material. These are supplemented with records as they appeared in current literature. Information and advice from many Agricultural Commissioners, Farm Advisors, coworkers and other friends are gratefully acknowledged.

GRAPHOLITHA MOLESTA (Busck) (oriental fruit moth)

Introduced into the United States sometime prior to 1915, oriental fruit moth gradually spread to all peach-growing areas east of the Rocky Mountains (Metcalf and Flint, 1962). This oriental pest of rosaceous fruits also occurs in Europe, Australia, North and South America. It is known primarily as a pest of peaches, doing serious damage by mining the twigs and burrowing in the fruit. It is a small olethreutid producing one to seven generations per year.

The first collection of oriental fruit moth in California was in Orange County late in 1942. Subsequent intensive survey efforts disclosed light infestations in neighboring Los Angeles, Riverside and San Bernardino counties early in 1943. Before the end of that year collections in Kern, Tulare, Stanislaus and Sutter counties precluded any possibility of an eradication program which had been considered. Continued intensive survey through the 1945 season added Kings, Fresno, Sacramento, Placer, Merced and Santa Clara counties. Some of the collections were single adult specimens from infestations so light that no more were taken until years later. Meanwhile oriental fruit moth was found for the first time in Colorado, Idaho, Oregon and Utah.

Until 1954 the pest was all but forgotten, although occasional collections of strays came from the southern counties. Large scale liberation of the introduced hymenopterous parasite *Macrocentrus ancylivorus* Rohwer may have helped to keep the population to a minimum. Somewhat contrary to expectations, the parasite became established and has persisted in some native host larvae, apparently from the last releases in 1946 to the present.

In 1953 bait trapping in Tulare, Fresno and Merced county orchards known to be infested several years earlier produced no specimens. But late in the 1954 season the first heavy outbreak in the state appeared at Kingsburg, involving Fresno, Kings and Tulare counties (Summers *et al.*, 1956). Oriental fruit moth then spread throughout the peach-growing portions of these three counties becoming heavy and general by 1961. Riverbottom lands suffer much the worst in these counties,

with peaches some distance from major streams consistently being only lightly infested.

Fifteen years after collection of a lone adult at Denair, Stanislaus County, oriental fruit moth appeared northeast of Modesto in 1958. The following year it was troublesome. Infestation around neighboring Escalon, San Joaquin County, was very heavy in 1963. Spread through Madera and Merced counties also had occurred, so that 1963 was a bad year throughout the San Joaquin Valley, including Kern County.

A similar pattern, centering around Gridley in Butte County, developed in the Sacramento Valley. Infestations apparently followed the channels of fruit movement, developing from the first collection about 1958 to major proportions in 1962–63. This center also involves peach-producing areas of Tehama, Sutter, Yuba, Placer and Sacramento counties.

Apparently oriental fruit moth now occupies most of its potential territory in central California, and has belatedly fulfilled expectations as a major pest of deciduous fruits, especially peaches.

Elsewhere, especially nearer the coast, oriental fruit moth so far has not appeared or has been negligible. There are scattered collection records from San Diego, Santa Barbara, Monterey, San Benito, Santa Clara, San Mateo and Colusa counties.

Paramyelois transitella (Walker) (navel orangeworm)

The taxonomic history of this phycitid moth dates from 1863, while a summary of distributional records indicates its occurrence from the southern United States to central South America (Heinrich, 1956). Attention was attracted in southern Arizona in 1921 by the larvae working in navel orange fruits. Although infestation was almost entirely limited to splits, fungus-infected or other previously damaged fruit, California authorities issued a Quarantine Circular against Arizona citrus. This was in effect from 1922 until 1930, when navel orangeworm was decided to be only a scavenger and the restriction lifted. Many other hosts are recorded. These could be summarized as almost any damaged, overripe or mummified fruit which is neither too wet nor too dry.

First California collections of navel orangeworm in Orange County late in 1942 attracted little attention. Adults appeared frequently during the next three years in diamalt bait traps used in large numbers for oriental fruit moth. Larvae were noted in their normal role as scavengers. Earliest records for Los Angeles, Riverside and San

Bernardino counties came in the summer of 1943; for Imperial and San Diego, in February 1944.

First indications of navel orangeworm as a serious pest came with a few collections in walnuts in Ventura and Santa Barbara counties in late 1947. The only previous record in walnut was in Orange County in 1943. The known host range was extended to include almonds in the Antelope Valley of Los Angeles County early in 1948.

Appearance of navel orangeworm at Fresno in late 1948 was followed by a survey which disclosed it in mummy fruits and walnuts at a few scattered locations, but not of general distribution. By 1949 it was spreading rapidly and recognized not only as a walnut pest, but threatening to almonds. New county records during that year were Tulare, Kern, Madera, Merced, Stanislaus, San Joaquin, Sacramento, Tehama, and Contra Costa. In the latter county it did not reach the walnut orchards in the western portion for several more years. In the Sacramento Valley, fill-in was rapid.

With minor exceptions, all walnut- and almond-growing areas in California are now considered infested, with greater damage to almonds in the more northern counties. Navel orangeworm is reported as of little importance in Yolo and Shasta counties. It often penetrates walnuts through codling moth entrance holes.

Central coast counties from Santa Cruz to San Luis Obispo are uninfested or practically so. No records from the north coast counties are known. Thus an insect known only as a scavenger has developed into a serious pest of walnuts and almonds in a 20-year period (Wade, 1961).

Potentialities of navel orangeworm as a citrus pest may have been discounted too early. Substantial losses of navel oranges due to larval infestation were reported late in 1969 from Oroville, Butte County, and Gustine, Merced County.

Rhagoletis completa Cresson (walnut husk fly)

Walnut husk fly, a serious pest of walnuts and occasionally found in late peaches, apparently is native to the Great Plains states (Boyce, 1934). It has a definite preference for soft-hulled over hard-hulled walnuts, with the soft blacks an important factor in population build-up and spread. Walnut husk fly first appeared in California in the Chino-Ontario-Pomona area in the fall of 1926, and soon became established as a troublesome pest. Early collection records indicate that it reached Riverside County in 1930, Orange County in 1937, and San Diego County in 1939. Some climatic limitation appeared to be in operation,

for walnut husk fly was not found in Ventura County until the fall of 1948.

The appearance of an infestation in Somona County, 300 miles farther north, in late 1954 seemed to justify an eradication attempt. This was unsuccessful. During 1957 the fly not only reached adjoining Napa County, but appeared in distant Santa Clara, Stanislaus and Merced counties. Collections in Santa Barbara County beginning in 1956 perhaps were the result of natural spread from Ventura.

Extension over the remainder of the state has been gradual, but by no means consistent. Populations in Merced County were heavy in the late 1950's, but with an abundance of effective traps in operation each season, the fly was not collected in Madera, Fresno, or Tulare counties until 1963 or 1964, or in Kings County until 1965. Infestations in Fresno, Kings and Tulare counties are still scattered and light. In Kern County, midway between heavy infestations of long standing, walnut husk fly has not yet been found on the floor of the San Joaquin Valley. Several collections were taken 1955–1957 in fringe and mountainous areas on both sides, including Bodfish, Tehachapi, Caliente, Frazier Park, and Maricopa.

Extension into some northern California counties may have been from either south or north, since walnut husk fly appeared in Oregon for the first time at Medford, in 1963. Although some more or less isolated walnut plantings seemingly have escaped infestation so far, there are now collection records from nearly all California counties where walnuts are grown. Trinity and Inyo seem to be exceptions. Tehama County, with considerable walnut acreage and a diligent trapping program, did not produce a collection record until September 1968. Northern county records vary from recent collections of a few stray adults (Del Norte, Siskiyou, Humboldt, Lassen, Shasta, Glenn, Colusa) to fairly heavy though spotty infestations of several years' standing (Butte, Lake, Mendocino). Sierra foothill counties from Fresno to Sierra all have light to heavy infestations in the lower portions where there is host material.

Of special interest are numerous collections of adult walnut husk fly under seemingly impossible conditions, and 50 or more miles from any possible host material. Adults are wanderers and strong fliers, but no explanation is offered for their presence in high mountain and desert areas. The most striking records, all since 1961, are: Coleville, Mono County; Markleeville and Fredericksburg, Alpine County; at 7,200 feet on the Sonora Pass Highway, and at 7,500 feet on the Tioga Pass Highway in Yosemite National Park, Tuolumne County. The latter

collection was repeated at the same location after a two-year interval. The upper limit for black and English walnuts at these latitudes is about 3,000 feet.

Cnephasia longana Haworth (omnivorous leaf tier)

The earliest American appearance of this European tortricid moth was in 1929 in the Willamette Valley of Oregon, from whence it spread over a large part of western Oregon and southwestern Washington (Edwards and Mote, 1936). Young larvae mine leaves; older larvae spin loose webbing and generally feed on growing foliage tips, and flowers. The host list is almost interminable, but strawberries have been the only fruit seriously attacked. There is but one annual generation. Eggs and young larvae spend summer, fall and winter in crevices of bark, cracks in posts and similar places. Small larvae are wind-dispersed on threads in early spring. This accounts for infestations being heaviest near trees, fences, and wooden pole lines.

Omnivorous leaf tier first was recognized in California in the spring of 1947 near the Stanford University campus. Obviously this appearance was due to introduction rather than to natural spread. In this portion of San Mateo County it did considerable damage to flax. The following year the known range was extended northward to San Francisco, with serious losses to flower growers in the Millbrae area (Middlekauf, 1949). In the early summer of 1949 large strawberry plantings near Sunol, Alameda County, were heavily infested, with considerable fruit being unmarketable (Allen, 1952). About the same time omnivorous leaf tier appeared in strawberries and numerous flower hosts from Santa Cruz southward into northern Monterey County. For several years there were apparently two separate infestations, centering around San Francisco and Monterey bays, respectively. Careful inspection up to 1950 indicated the northern and eastern limits to be Petaluma in Sonoma County, Napa in Napa County, Rockville in Solano County, and Livermore in Alameda County.

Considering the great abundance of host material, and the history in Oregon, 20 years have not added greatly to the known distribution of omnivorous leaf tier in California. There have been no outbreaks approaching those of 1948–49. Strawberry growers have had some sporadic trouble, but now keep this moth completely in check with insecticides. The moth obviously requires a coastal climate and is unlikely to move farther inland, although it occurs farther inland in Oregon. Failure to extend its range appreciably up and down the coast is less understandable. The two original infestations came together

some years ago in Santa Clara and Santa Cruz counties. Recent surveys in wild flowers indicate that continuous infestation extends no farther than Healdsburg in Sonoma County, Oakville in Napa County, San Juan Bautista in San Benito County, and Greenfield in Monterey County. However, stray collections have been taken at Stafford 14 June 1960 and Loleta 25 May 1965 in Humboldt County, and at Edna 28 April 1967 in San Luis Obispo County.

CEUTORHYNCHUS ASSIMILIS Paykull (cabbage seedpod weevil)

This small gray European weevil in the larval stage is destructive to cruciferous seed crops. The first North American record (1931) was in the heart of the major cabbage seed-growing area in Washington state, and subsequent losses were sometimes of major proportions (Hanson *et al.*, 1948). Rapid spread is augmented by the general abundance of wild hosts, particularly mustards and radishes. Subsequently the weevil appeared in Idaho and Oregon.

Appearance of cabbage seedpod weevil in the San Francisco Bay region in the mid-1940's was obviously due to an introduction (Hagen, 1946). Infestation in Del Norte, western Siskiyou and northern Humboldt counties by 1950 probably was the result of natural spread from Oregon. The earliest California record is Brentwood, Contra Costa County, May 1945. By 1950 the weevil had spread to include parts of Marin, Sonoma, Napa, Solano, Sacramento and Yolo counties. Movement southward in the San Joaquin Valley ended with very light populations in Merced County. Attempts to repeat collection of the species at Santa Rita on Highway 152, based on a stray adult taken in May, 1950, have been futile. Apparently the line has held ever since.

Cabbage seedpod weevil spread farther southward in coastal counties, including Santa Clara and northern San Benito, but reached a temporary limit for some years in the vicinity of King City, Monterey County. In 1956, what appeared to be a local infestation developed near Arroyo Grande, San Luis Obispo County. The earliest Santa Barbara County collection record is from Gaviota in 1961. Distribution gaps in intervening coastal territory gradually filled in. Careful survey in the spring of 1967 indicated that the distribution of the weevil was continuous as far south as Ventura and Sespe in Ventura County, where it abruptly terminated. However, there are collection records from Buena Park and Fullerton in Orange County, 50 miles farther southeast, dated early 1965; there are none from Los Angeles County.

Since populations in central coast counties and in Washington have been heavy, rapid and thorough occupation of intervening territory

would be logical. This has not been the case. After 20 years, distribution is more or less continuous through the north coastal counties, but populations are not heavy. The weevil is continuous northward in the Sacramento Valley only to Marysville and Yuba City. Numerous efforts have turned up but a few isolated collections in Lake, Butte, Tehama and Shasta counties, and none in Colusa or Glenn. The weevil has penetrated the Sierra Nevada foothills, with collections recorded from western Nevada, Placer, Amador, Calaveras and Tuolumne counties.

Cabbage seedpod weevil activities in California are now of little more than academic interest. Growers of cruciferous seed crops in the central coast area have had sporadic trouble with this weevil in past years. Acreages of these crops have declined, and those remaining are well protected with insecticides.

Lepidosaphes ficus (Signoret) (fig scale)

Fig scale, probably of Mediterranean origin, is thought to have been introduced into California at Fresno in 1905 on fig cuttings from Algeria (Simmons *et al.*, 1931). It spread very slowly, the known infestation having a radius of less than a mile in 1917. By 1931 it had spread some 60 miles to the southeast. The pest gradually spread over the east side of the San Joaquin Valley from Stockton to the Kern County line. Fig scale is usually found on the leaves, twigs and fruit of figs, but there are a few records for elm and walnut. Dispersal beyond those geographical limits has been almost negligible, although there is no lack of host material in most parts of the state. Fig scale was not found in Bakersfield until 1952, and it never has been a problem in Kern County. Although continuous on the east side, fig scale never has been found on the west side of the San Joaquin Valley.

Within these limits fig scale apparently spread slowly but surely, and became a serious pest where host material was contiguous. This accounts for the spread and build-up in the fig-growing portions of Fresno, Madera, Merced, and Tulare counties. It seems unable to move more than very short distances unless carried. Occurrences of fig scale outside the contiguous area are limited to very small widely scattered spot infestations. A few specimens were taken on a ranch in central Santa Clara County in 1939. However, a thorough search of the locality in 1966 indicated that the scale had disappeared completely. A small infestation found at Orland, Glenn County, in 1947 persists but has spread little in 20 years. Fig scale was found in San Diego County as early as 1941. By 1953 there were infestations of minor significance

in Vista, Carlsbad, and Escondido. About the same time, specimens were taken at three locations in central Orange County. In the city of Sacramento, two small separated infestations appeared in 1964. An isolated fig tree in the mountains above Jackson, Amador County, was found to have fig scale in 1960.

Infestation of figs in the central San Joaquin Valley was generally heavy and troublesome during the 1930's and 1940's. Since 1950 populations have lagged, although occasional local outbreaks have required insecticides. A logical explanation for the decline is the introduction of a hymenopterous parasite, *Aphytis* sp., in 1949 (Doutt, 1954). Previous attempts to establish parasites were unsuccessful, but this one soon began to produce results.

There may be some climatic limitation on the spread of fig scale out of the San Joaquin Valley. Sporadic outbreaks in its present range are to be expected, but the presence of effective parasites may keep it below economic levels.

ASTEROLECANIUM ARABIDIS (Signoret) (pit-making pittosporum scale)

Of European origin, this pit-making scale is also known in several eastern states. The earliest American record is in 1925. The mature scale is small, convex, creamy-white to tan, with a delicate white fringe around the margin. The host list is very diverse, but only a few common hosts will be considered here. Conspicuous symptoms of infestation are pitting, swelling, and distortion of the host plant.

Two separate patterns of distribution in California must be considered: in native and in cultivated hosts. Deerweed, *Lotus scoparius* (Nutt.) Ottley, a common native legume, is not the only wild host but is the most important one. Cultivated hosts include a great diversity of families and species, usually grown at a considerable distance from wild hosts.

The earliest official collection of *A. arabidis* in California was in western Contra Costa County on deerweed in 1940 (Essig, 1945). Later surveys disclosed infestations on the same host in Alameda, Marin, San Mateo, Santa Clara and Santa Cruz counties. *A. arabidis* was found at Stockton in 1944, seriously damaging *Pittosporum tobira* Aiton (the most commonly infested cultivated host) and privet (*Ligustrum* sp.). Small scattered infestations in cultivated hosts were found in Alameda, Contra Costa, Marin, Napa, Santa Clara, Solano and Sonoma counties by 1950. Only at Stockton has infestation in cultivated hosts become widespread, and privet attacked to any extent. From 1944 to the early 1950's most *P. tobira* and privet in that city were badly

distorted from scale infestation. There are no known wild hosts in the vicinity.

Deerweed is a common shrub in the Coast Ranges, from Humboldt County to the southern end of the state, and somewhat less abundant in the Sierra foothills. Occurrence of pit-making scale on this host is rather general from the Mendocino-Sonoma county line south to the Carmel Valley in northern Monterey County. Although the distribution of host material is continuous there are no records from coastal areas farther south, excepting one on cultivated *Pittosporum tobira* at Paso Robles, San Luis Obispo County, in 1963. Scattered Sierra foothill records on deerweed, mostly dating back many years, include El Dorado, Amador and Mariposa counties.

Infestation in cultivated plants has been of much concern because of the severity of damage and the wide host range. Early records in San Joaquin and the bay counties were followed by collections in the counties of Sacramento, 1947; Yolo, 1948; Tulare, 1948; Tuolumne, 1951; Fresno, 1951; El Dorado, 1952; Butte, 1956; Yuba, 1956; Sutter, 1959; Mendocino, 1960 and Glenn, 1969. While in mountain counties infestation could have spread from native hosts, those on the valley floor probably resulted from movement of scales on cultivated host material. Only infestations in established plantings are here considered; many collection records and a greater host list could be reported from nursery surveys. Large gaps in the distribution within the San Joaquin Valley have been partially filled with collections in the counties of Stanislaus, 1958; Kern, 1965, and Kings, 1969. There are no records from farther south.

Although no effective parasites are known, pit-making scale has declined sharply in recent years. Infestations are much less common and severe, even in Stockton. Good trimming and treatment of infested shrubs greatly reduce severity, and sometimes seem to eliminate the scale. Present infestations in cultivated hosts, however severe, are spotty and scattered. There is no satisfactory explanation for the means of dispersal, the geographic limits or the current decline of this species. Pit-making scale is a pest which might get out of control at any time.

LECANIUM KUNOENSIS Kuwana (kuno scale)

Although kuno scale was not described until 1907, from Japanese material, early authorities reported what undoudtedly was this species in the Oakland hills in 1896 (McKenzie, 1951). Principal hosts are rosaceous, especially plum, peach, apple, pear, quince, cherry, almond,

hawthorn, and *Cotoneaster*. There are records on English walnut, and California buckeye (*Aesculus californica* (Spach) Nutt.). Kuno scale builds up heavy populations, produces honeydew, and causes serious loss of tree vitality.

Kuno scale is known to occur only in Japan and California. Delimitation surveys in 1946 indicated an extent of about 100 square miles involving western Contra Costa and northern Alameda counties, at elevations not exceeding 500 feet. With an abundance of host material in all directions, there seems to be no explanation for the failure of this scale to spread farther by natural means in a period of 70 years.

Limited distribution in one area is no proof that an insect will not live or do well in another. Kuno scale was found in Butte County at Chico, 160 miles farther north and under central valley conditions, in 1960. The following year it appeared at Paradise, 15 miles northeast of Chico, in the foothills, and at an elevation of 1,700 feet. Infestation at Chico was limited to a few contiguous hosts in a residential district, and apparently has been eradicated by the Butte County Department of Agriculture. The scale has been more severe and widespread at Paradise, and a considered eradication attempt was precluded when the native plum *Prunus subcordata* Benth. was found to support scale populations.

In 1966 kuno scale appeared at Lakeport, elevation 1,300 feet, in Lake County. This is about 80 miles west of Paradise, and the same distance north from the original Alameda-Contra Costa infestation. Infestation apparently is limited to a few small properties, and eradication by county authorities is under consideration.

Sudden extension of range and distant outbreaks of a pest long resident to a limited area are unexplainable phenomena with which entomologists have to deal. There is no real basis for prediction, but kuno scale could follow the pattern of walnut husk fly and sooner or later become general in distribution.

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Extended Diapause in *Coloradia pandora* Blake

(Lepidoptera: Saturniidae)

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The pandora moth, *Coloradia pandora* Blake, is a periodic pest of pine forests in western United States. It is one of the largest defoliating insects in North America and an obvious food source for many forest dwellers, including man; Aldrich (1921) and Essig (1934) have documented its use by Indian tribes. Principal hosts are ponderosa pine, *Pinus ponderosa* Laws., Jeffrey pine, *P. jeffreyi* Grev. & Balf., and lodgepole pine, *P. contorta* Dougl. Larvae feed in fall, overwinter, and feed again in spring in an exposed position on pine branches. Pupae are formed in early summer in loose mineral soil at a depth of 1 to 5 inches where they overwinter.

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